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Cosmological Consequences of a Quantum Theory of Mass and Gravity

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Abstract

The understanding of several cosmological problems that has been obtained from the development of the Generation Model (GM) of particle physics is presented. The GM is presented as a viable simpler alternative to the Standard Model (SM). The GM considers the elementary particles of the SM to be composite particles and this substructure leads to new paradigms for both mass and gravity, which in turn lead to an understanding of several cosmological problems: the matter-antimatter asymmetry of the universe, dark matter and dark energy. The GM provides a unified origin of mass and the composite nature of the leptons and quarks of the GM leads to a solution of the cosmological matter-antimatter asymmetry problem. The GM also provides a new universal quantum theory of gravity in terms of a residual interaction of a strong color-like interaction, analogous to quantum chromodynamics (QCD). This very weak residual interaction has two important properties: antiscreening and finite range, that provide an understanding of dark matter and dark energy, respectively, in the universe.

Keywords: generation model, gravity, dark matter, MOND theory, dark energy, antimatter, big bang

1. Introduction

The main purpose of this chapter is to present the contributions to an understanding of several cosmological problems that have been obtained from the development of an alternative to the Standard Model (SM) of particle physics [1]. This alternative model, named the Generation Model (GM) [2], not only describes all the transition probabilities for interactions involving all the elementary particles of the SM but also provides new paradigms, including the origin of both mass [3] and gravity [4].

The GM considers the elementary particles, the six leptons, six quarks and three weak bosons, of the SM to be composite particles. Their constituents are called rishons and antirishons. It will be demonstrated that this substructure leads to new paradigms for both mass and gravity, which in turn lead to an understanding of several cosmological problems: the matter-antimatter asymmetry of the universe, dark matter and dark energy.

It will be shown that the GM provides a unified origin of mass in which the mass of a particle is described in terms of the energy content of its constituents [5], while in the SM, the elementary leptons, quarks and weak bosons, are described in terms of the Higgs mechanism [6, 7]. It will be demonstrated that the composite nature of the leptons and quarks of the GM leads to a solution of the cosmological matter-antimatter asymmetry problem.

In particular, it will be shown that the GM provides a new universal theory of gravity in terms of a residual interaction of a strong color-like interaction [4], analogous to quantum chromodynamics (QCD) [8], the theory of strong interactions, in the SM. This very weak residual interaction has two important properties: asymptotic freedom (antiscreening) [9, 10] and finite range [11], that provide an understanding of dark matter [12] and dark energy [13], respectively, in the universe.

Section 2 discusses the *incompleteness* of the SM and examines some basic assumptions upon which the SM has been built. Section 3 introduces the GM which replaces several *dubious assumptions* within the SM by different and simpler assumptions, without destroying any agreement with experiment. These lead to the notion that the elementary particles, the six leptons, six quarks and three weak bosons of the SM are *composite particles*. Section 4 describes the development of a viable composite GM in which the elementary particles of the SM are composites of elementary spin-1/2 particles called rishons and antirishons. Section 5 discusses a *new paradigm* provided by the composite GM for *all* mass, and indicates a qualitative understanding of the mass hierarchy of leptons and quarks.

Section 6 presents a solution to the *cosmological matter-antimatter asymmetry problem* in terms of the composite GM. The composite GM also leads to a *new paradigm* for *gravity*. This is discussed in Section 7 in which a *quantum theory of gravity* is described. This new law of universal gravitation is shown to provide an understanding of both *dark matter* (Section 8) and *dark energy* (Section 9).

Section 10 discusses the possibility that the photon may be considered to be the singlet state of the corresponding QCD color octet binding together the constituents of the leptons and quarks. Finally, Section 11 gives a brief summary and conclusion.

2. Standard model of particle physics

The current formulation of the Standard Model (SM) of particle physics [1] was essentially finalized in the mid-1970s following the experimental confirmation of the existence of quarks [14, 15]. However, the model is regarded by most physicists as *incomplete* since it provides little understanding of several empirical observations. First, it does not explain the occurrence of three “generations” of the elementary particles of the SM [16]: the first generation comprising

the up and down quarks, the electron and its neutrino, the second generation comprising the charmed and strange quarks, the muon and its neutrino and the third generation comprising the top and bottom quarks, the tau and its neutrino. Each generation behaves similarly except for mass. Second, it does not provide a unified description of the origin of mass nor describe the mass hierarchy of leptons and quarks. The SM also fails to describe the nature of gravity, dark matter, dark energy or the cosmological matter-antimatter asymmetry problem.

Because of the incompleteness of the SM, the basic assumptions upon which the SM has been erected have been examined [17]. There are three basic assumptions, which are considered to be *dubious* and also present major stumbling blocks preventing progress beyond the SM. These are (i) the assumption of a diverse complicated scheme of additive quantum numbers to classify its elementary particles; (ii) the assumption of weak isospin doublets in the quark sector to accommodate the universality of the charge-changing weak interactions and (iii) the assumption that the weak interactions are fundamental interactions described by a local gauge theory.

The elementary particles of the SM are six leptons: electron (e^-), electron neutrino (ν_e), muon (μ^-), muon neutrino (ν_μ), tau (τ^-), tau neutrino (ν_τ) and six quarks: up (u), down (d), charmed (c), strange (s), top (t) and bottom (b). These twelve particles all have spin-1/2 and are allotted several additive quantum numbers: charge Q , lepton number L , muon lepton number L_μ , tau lepton number L_τ , baryon number A , strangeness S , charm C , bottomness B and topness T (see **Table 1**). For each particle additive quantum number N , the corresponding antiparticle has the additive quantum number $-N$.

Table 1 demonstrates that this classification of the elementary particles in the SM is *nonunified*, since, except for charge, the leptons and quarks are allotted different kinds of additive quantum numbers. This diverse complicated scheme of additive quantum numbers for its elementary particles constitutes a basic problem for the SM, especially if the leptons and quarks are *not* elementary particles (see Section 4).

A second problem with the SM involves the method it uses to accommodate the universality of the charge-changing (CC) weak interactions, mediated by the W^+ and W^- bosons.

In the SM, the mass eigenstate leptons have weak isospin 1/2, whose third component is related to both charge and lepton number. Restricting the discussion in this chapter to only the first two generations for simplicity means that the two neutrinos interact with their corresponding charged leptons with the full strength of the CC weak interaction and do not interact at all with the other charged lepton. This is guaranteed by the conservation of lepton numbers.

On the other hand the universality of the CC weak interactions in the quark sector is treated differently. It is assumed that the u and c quarks form weak isospin doublets with so-called weak eigenstate quarks d' and s' , respectively, where again for simplicity, the small mixing with the third generation quark b is neglected:

$$d' = d \cos\theta + s \sin\theta, \tag{1}$$

and

$$s' = -d \sin\theta + s \cos\theta, \tag{2}$$

Particle	Q	L	L_μ	L_τ	A	S	C	B	T
e^-	-1	1	0	0	0	0	0	0	0
ν_e	0	1	0	0	0	0	0	0	0
μ^-	-1	1	1	0	0	0	0	0	0
ν_μ	0	1	1	0	0	0	0	0	0
τ^-	-1	1	0	1	0	0	0	0	0
ν_τ	0	1	0	1	0	0	0	0	0
u	$+\frac{2}{3}$	0	0	0	$\frac{1}{3}$	0	0	0	0
d	$-\frac{1}{3}$	0	0	0	$\frac{1}{3}$	0	0	0	0
c	$+\frac{2}{3}$	0	0	0	$\frac{1}{3}$	0	1	0	0
s	$-\frac{1}{3}$	0	0	0	$\frac{1}{3}$	-1	0	0	0
t	$+\frac{2}{3}$	0	0	0	$\frac{1}{3}$	0	0	0	1
b	$-\frac{1}{3}$	0	0	0	$\frac{1}{3}$	0	0	-1	0

Table 1. SM additive quantum numbers for leptons and quarks.

and θ is a mixing angle introduced by Cabibbo [18] into the transition amplitudes prior to the development of the quark model in 1964. In the quark case the third component of weak isospin is related to both charge and baryon number.

The u and c quarks are assumed to interact with the weak eigenstate quarks d' and s' , respectively, with the full strength of the CC weak interaction. In addition the u and c quarks are assumed to not interact at all with the weak eigenstate quarks s' and d' , respectively. This assumption is dubious, since there are no conserved quantum numbers to support this assumption.

A third problem with the SM concerns the origin of mass. In the SM, the masses of hadrons arise mainly from the energy content of their constituent quarks and gluons, in agreement with Einstein's conclusion [5]. On the other hand the masses of the elementary particles, the leptons, the quarks and the W and Z bosons are interpreted differently, arising from the existence of the so-called Higgs field [6, 7]. The Higgs field was introduced mathematically to spontaneously break the $U(1) \times SU(2)$ local gauge symmetry of the electroweak interaction to generate the masses of the W and Z bosons. The Higgs field also cured the associated fermion mass problem: by coupling, with appropriate strength, originally massless fermions to the scalar Higgs field, it is possible to produce the observed fermion masses and to maintain local gauge invariance [19].

There are several problems with the SM's interpretation of the origin of mass. First, there is no clear evidence for the existence of the hypothetical Higgs field. Second, the model provides no *unified* origin of mass. Third, the fermion-Higgs coupling strength is dependent upon the mass of the fermion so that a new parameter is introduced into the SM for each fermion mass. In fact fourteen new parameters are required, if one includes two more parameters to describe the masses of the W boson and the Higgs particle. Fourth, the Higgs mechanism does *not provide any physical explanation* for the origin of the masses of the elementary particles.

The assumption that the weak interactions are fundamental interactions arising from a local gauge theory, unlike both the electromagnetic and strong colour interactions, is at variance with the experimental facts: both the W and Z particles, mediating the weak interactions, are massive, and this conflicts with the requirement of a local gauge theory that the mediating particles should be massless in order to guarantee the gauge invariance. This assumption is very dubious, especially since it leads to more problems than it solves. It also leaves several questions unanswered: *How does the spontaneous symmetry breaking mechanism occur within the electroweak theory? What is the principle that determines the large range of fermion masses exhibited by the leptons and quarks?*

3. Generation model of particle physics

The GM of particle physics [2, 17] overcomes many of the problems inherent in the SM. In the GM the three dubious assumptions of the SM discussed previously are replaced by three different and simpler assumptions. These are (i) the assumption of a *simpler unified* classification of leptons and quarks; (ii) the assumption that the *mass eigenstate quarks* form weak isospin doublets and that hadrons are composed of *weak eigenstate quarks* and (iii) the assumption that the weak interactions are *not fundamental interactions*.

Table 2 shows the additive quantum numbers allotted to both leptons and quarks in the GM. This is a much simpler and unified classification scheme involving only three additive quantum numbers: charge Q , particle number p and generation quantum number g . All three quantum numbers are conserved in all interactions. In particular the generation quantum number g is strictly conserved in weak interactions unlike some of the quantum numbers, e.g. strangeness S , of the SM. As for **Table 1** the corresponding antiparticles have the opposite sign for each particle additive quantum number.

The conservation of the generation quantum number in weak interactions was only achieved by making two postulates, which means that the GM differs fundamentally from the SM in two more ways [20, 21]. First the GM postulates that it is the mass eigenstate quarks of the same generation, which form weak isospin doublets: (u, d) and (c, s) . Thus the GM assumes, in the two generation approximation, that the u and c quarks interact with d and s , respectively, with the *full* strength of the CC weak interaction and that the u and c quarks do *not* interact at all with s and d , respectively. This result is a consequence of the conservation of the generation quantum number. Second, while the SM assumes that hadrons are composed of mass eigenstate quarks such as d and s , the GM postulates that hadrons are composed of the corresponding weak eigenstate quarks d' and s' . These two postulates overcome the second dubious assumption of the SM.

Particle	Q	p	g	Particle	Q	p	g
ν_e	0	-1	0	u	$+\frac{2}{3}$	$\frac{1}{3}$	0
e^-	-1	-1	0	d	$-\frac{1}{3}$	$\frac{1}{3}$	0
ν_μ	0	-1	± 1	c	$+\frac{2}{3}$	$\frac{1}{3}$	± 1
μ^-	-1	-1	± 1	s	$-\frac{1}{3}$	$\frac{1}{3}$	± 1
ν_τ	0	-1	$0, \pm 2$	t	$+\frac{2}{3}$	$\frac{1}{3}$	$0, \pm 2$
τ^-	-1	-1	$0, \pm 2$	b	$-\frac{1}{3}$	$\frac{1}{3}$	$0, \pm 2$

Table 2. GM additive quantum numbers for leptons and quarks.

The classification scheme given in **Table 2** provides a simpler and unified description of leptons and quarks. It also suggests that leptons and quarks are related and in particular allows the development of a composite model of leptons and quarks [4, 22].

The GM assumes that the leptons, quarks and the W and Z bosons are *composites*. Consequently, the weak interactions are *not* fundamental interactions arising from an $SU(2)$ local gauge theory. They are residual interactions of the strong color interaction binding the constituents of the leptons, quarks and the W and Z bosons together. This strong color interaction is completely analogous to that of QCD in the SM. The composite nature of leptons, quarks and the W bosons overcomes the dubious assumption of the SM that the weak interactions are fundamental. It should be noted that the treatment of the electromagnetic and weak interactions in the SM in terms of a $U(1) \times SU(2)$ local gauge theory is replaced in the GM by a $U(1) \times SU(2)$ global gauge theory [23].

The GM has only the charge Q additive quantum number in common with the SM (see **Tables 1** and **2**). The second additive quantum number of the GM, particle number p , replaces both baryon number A and lepton number L of the SM, while the third additive quantum number of the GM, generation quantum number g , effectively replaces the remaining additive quantum numbers, L_μ, L_τ, S, C, B and T of the SM.

4. Composite generation model

Although there is no direct experimental evidence that leptons and quarks have a substructure, there is considerable indirect evidence that leptons and quarks are actually *composites*.

First, the equal magnitude of the electric charges of the electron and proton, indicates that the charges of the up and down quarks are related to that of the electron.

Second, the leptons and quarks are considered [16] to form three families or generations, containing particles which have similar properties, except for mass. This feature is analogous to Mendeleev’s periodic table of the elements, based essentially on elements having similar properties, except for mass. The existence of three repeating patterns suggests strongly that the members of each generation are composites, analogous to the elements of the periodic table.

The nonunified classification scheme of the SM provides a major stumbling block for the development of a composite model of leptons and quarks. On the other hand, the unified classification scheme of the GM (**Table 2**) makes feasible a composite version of the GM (CGM) [22]. Here we shall present the current version [4].

The composite GM is based on the unified classification scheme and also on 1979 composite models of Harari [24] and Shupe [25]. The current composite GM was proposed in 2011 and is described in detail in Chapter 1 [2] of the book *Particle Physics* published by InTech and in a review paper [17] published in *Advances in High Energy Physics*.

Both the models of Harari and Shupe are very similar and treat leptons and quarks as composites of two kinds of spin-1/2 particles, which Harari named “rishons” from the Hebrew word for primary. The CGM adopts this name for the constituents of both leptons and quarks and for consistency the same three additive quantum numbers are assigned to the constituents as were previously allotted in the GM to leptons and quarks (see **Table 2**).

In the Harari-Shupe Model (HSM), two kinds of rishons labeled T with charge $Q = +\frac{1}{3}$ and V with $Q = 0$ and their corresponding antiparticles labeled \bar{T} with charge $Q = -\frac{1}{3}$ and \bar{V} with $Q = 0$, are employed to construct the leptons, quarks and their antiparticles. In the HSM, each spin-1/2 lepton or quark is composed of three rishons or three antirishons.

Table 3 shows the proposed HSM structures of the first generation of leptons and quarks. Basically the HSM describes only the charge structure of the first generation of leptons and quarks and does not provide a satisfactory understanding of the second and third generations.

Particle	Structure	Q
e^+	TTT	+1
u	TTV	$+\frac{2}{3}$
\bar{d}	TVV	$+\frac{1}{3}$
ν_e	VVV	0
$\bar{\nu}_e$	$\bar{V}\bar{V}\bar{V}$	0
d	$\bar{T}\bar{V}\bar{V}$	$-\frac{1}{3}$
\bar{u}	$\bar{T}\bar{T}\bar{V}$	$-\frac{2}{3}$
e^-	$\bar{T}\bar{T}\bar{T}$	-1

Table 3. HSM of first generation of leptons and quarks.

To overcome some of the deficiencies of the simple HSM, the two-rishon model was extended [4, 22], within the framework of the CGM, by the introduction of a *third* kind of rishon labeled *U* and the allocation of all three additive quantum numbers, *Q*, *p* and *g* to each kind of rishon (see **Table 4**). It should be noted that each rishon additive quantum number *N*, the corresponding antirishon has the additive quantum number $-N$.

In the CGM, the substructure of the leptons and quarks is described in terms of massless rishons and/or antirishons. Each rishon carries a color charge, red, green or blue, while each antirishon carries an anticolor charge, antired, antigreen or antiblue. The constituents of leptons and quarks are bound together by a strong color-type interaction, corresponding to a local gauged *SU*(3) symmetry (analogous to QCD in the SM) mediated by massless *hypergluons* (analogous to gluons in the SM).

Table 5 gives the structures of the first generation of leptons and quarks in the CGM. The *u*-quark has $p = +\frac{1}{3}$ since it contains two *T*-rishons and one \bar{V} -antirishon. It is essential that the *u*-quark should contain an \bar{V} -antirishon rather than a *V*-rishon as in the HSM, since its particle number is required to agree with its baryon number $A = +\frac{1}{3}$. It should be noted that leptons

Rishon	<i>Q</i>	<i>p</i>	<i>g</i>
<i>T</i>	$+\frac{1}{3}$	$+\frac{1}{3}$	0
<i>V</i>	0	$+\frac{1}{3}$	0
<i>U</i>	0	$+\frac{1}{3}$	-1

Table 4. CGM additive quantum numbers for rishons.

Particle	Structure	<i>Q</i>	<i>p</i>	<i>g</i>
e^+	<i>TTT</i>	+1	+1	0
<i>u</i>	<i>TTV̄</i>	$+\frac{2}{3}$	$+\frac{1}{3}$	0
\bar{d}	<i>TV̄V̄</i>	$+\frac{1}{3}$	$-\frac{1}{3}$	0
ν_e	$\bar{V}\bar{V}\bar{V}$	0	-1	0
$\bar{\nu}_e$	<i>VVV</i>	0	+1	0
<i>d</i>	$\bar{T}\bar{V}\bar{V}$	$-\frac{1}{3}$	$+\frac{1}{3}$	0
\bar{u}	$\bar{T}\bar{T}\bar{V}$	$-\frac{2}{3}$	$-\frac{1}{3}$	0
e^-	$\bar{T}\bar{T}\bar{T}$	-1	-1	0

Table 5. CGM of first generation of leptons and quarks.

are composed of three rishons, while quarks are composed of one rishon and one rishon-antirishon pair.

Each lepton of the first generation is *colorless*, composed of three rishons carrying different colors. Each quark of the first generation is *colored*, composed of one rishon and one colorless rishon-antirishon pair. The first generation of particles are all built out of T and V rishons and their antiparticles so that each particle has $g = 0$. The second and third generations are identical to the first generation plus one and two *colorless* rishon-antirishon pair(s): $\bar{U}V$ or $\bar{V}U$ with $Q = p = 0$ but $g = \pm 1$ so that the second and third generations have $g = \pm 1$ and $g = 0, \pm 2$, respectively. This gives *three repeating patterns* [2].

It should be noted that if each of the three kinds of rishons is *conserved* then each of the three additive quantum numbers, Q , p and g is also conserved in all interactions [22].

5. Mass

Since the mass of a hadron arises mainly from the energy of its constituents [26–28], the CGM suggests [3] that the mass of a lepton, quark or weak boson arises from a characteristic energy E associated with its constituent rishons and hypergluons, according to $m = E/c^2$. Thus the CGM provides a *new paradigm* and a *unified* description for the origin of *all* mass: the mass of a body arises from the energy content E of its constituents. The mass is given by $m = E/c^2$ in agreement with Einstein's conclusion [5], so that there is no need for the existence of a Higgs field with its accompanying problems. A corollary of this idea is: *If a particle has mass, then it is composite.*

The CGM suggests that the mass hierarchy of the three generations arises from the substructures of the leptons and quarks. The mass of each composite particle is expected to be *greater* if the constituents are on average more widely spaced: this is a consequence of the nature of the strong color interactions, which are assumed to possess the property of “asymptotic freedom” [9, 10], whereby the color interactions become stronger for larger separations of the color charges. Particles with two or more like charged rishons will have larger structures due to electric repulsion.

Qualitatively, for the same generation, one expects that (i) a charged lepton will have a greater mass than the corresponding neutral lepton; (ii) a $Q = +\frac{2}{3}$ quark will have a greater mass than the corresponding $Q = -\frac{1}{3}$ quark. These are both generally true: (i) the electron has a larger mass than its corresponding neutrino, and (ii) the top quark mass (173 GeV) is $>$ the bottom quark mass (4.2 GeV), the charmed quark mass (1.3 GeV) is $>$ the strange quark mass (95 MeV), although the up quark mass (2 MeV) is $<$ the down quark mass (5 MeV). The first generation quarks seem to present an anomaly since the proton consists of two up quarks and one down quark while the neutron consists of two down quarks and one up quark so that the proton is only stable if the down quark ($Q = -\frac{1}{3}$) is more massive than the up quark ($Q = +\frac{2}{3}$). In the CGM, this anomaly is accounted for by the constituents of hadrons being weak-eigenstate quarks rather than mass-eigenstate quarks. The proton is stable since the weak eigenstate quark d' has a larger mass than the up quark, containing about 5% of the strange quark mass, since $\sin^2\theta \approx 0.05$ [29].

6. Matter-antimatter asymmetry problem

According to the prevailing cosmological model [30] the universe was created in the so-called “Big Bang” from pure energy, and is currently composed of about 5% ordinary matter, 27% dark matter and 68% dark energy. It is generally assumed that the Big Bang and its aftermath produced *equal numbers* of particles and antiparticles, although the universe today appears to consist almost entirely of matter (particles) rather than antimatter (antiparticles). This constitutes the matter-antimatter asymmetry problem: *Where have all the antiparticles gone?* Currently there is no acceptable understanding of this asymmetry problem.

An understanding of the matter-antimatter asymmetry requires a precise definition of both matter and antimatter and knowledge of the physical nature of the Big Bang but unfortunately this knowledge is currently far from complete. The prevailing model of the Big Bang is based upon the theory of general relativity [31]: extrapolation of the expansion of the universe backwards in time yields an infinite density and temperature at a finite time in the past (approximately 13.8 billion years ago). Thus the “birth” of the universe seems to be associated with a “singularity”, which not only signals a breakdown of general relativity but also all the laws of physics. This leads to serious impediments to understanding the physical nature of the Big Bang and consequently the development of the matter-antimatter asymmetry in the aftermath of the Big Bang.

Since the physical nature of the Big Bang is still not understood, it is not possible to discuss the matter-antimatter asymmetry problem from the initial singularity. Consequently, the matter-antimatter (i.e. particle-antiparticle) asymmetry problem will be discussed in terms of the observed nature of the universe, ignoring the singularity.

In the SM the universe is made essentially of matter comprising three kinds of elementary particles: electrons, up quarks and down quarks. The matter described by the SM refers to the 5% ordinary matter, which prior to the nucleosynthesis, i.e. the fusion into heavier elements, consisted of about 92% hydrogen atoms and 8% helium atoms [32], so that the ordinary matter of the universe was, and still is, essentially electrically neutral and colorless.

For many decades now the SM has been unable to provide an acceptable understanding of the matter-antimatter asymmetry problem. The main reason seems to be that the SM assumes that the leptons and quarks are elementary particles. Since this implies no relationship between leptons and quarks, as indicated by the different sets of additive quantum numbers employed by the SM to describe their interactions, this allows the matter/antimatter nature of leptons and quarks to be decided by pure convention. In the SM both leptons and quarks are assumed to be matter particles.

In the SM, neglecting the singularity, it is assumed that the Big Bang initially produces numerous elementary particle-antiparticle pairs such as electron-positron pairs and quark-antiquark pairs by converting energy into mass according to $m = E/c^2$. Thus the early universe consisted of a soup of particle-antiparticle pairs continually being created and annihilated. Later, as the universe cooled following an inflationary period, the quarks and antiquarks would form protons, neutrons, antiprotons, antineutrons, etc., and eventually atoms of hydrogen, antihydrogen,

helium and antihelium. These would later annihilate in pairs until only atoms of hydrogen and helium prevailed. In this scenario, it seems unlikely that either electrons or positrons would prevail so that neither hydrogen atoms nor antihydrogen atoms would prevail. This simply reflects that the creation and annihilation of electron-positron pairs constitute a unique process, since in the SM both electrons and positrons are elementary particles.

In the GM, neglecting the singularity, it is expected that the Big Bang would initially produce numerous elementary rishon-antirishon pairs. Then as the universe cooled following an inflationary period, the rishons and antirishons would form leptons, quarks and their antiparticles and eventually atoms of hydrogen, antihydrogen, helium and antihelium. These would later annihilate in pairs until only atoms of hydrogen and helium prevailed.

In order to understand this matter-antimatter asymmetry, it is necessary to define the matter/antimatter nature of composite particles. Historically, the term “particle” defines matter that is naturally occurring, i.e. electrons, protons, hydrogen atoms, etc. This is consistent within the SM in which the electron and the up and down quarks are elementary particles. However, it is not consistent within the GM in which the electron and the up and down quarks are composite particles consisting of elementary particles (rishons) and/or antiparticles (antirishons). In the GM, rishons are considered to be matter (particles) while antirishons are considered to be antimatter (antiparticles), since rishon-antirishon pairs are considered to be created/annihilated in the standard manner, e.g. in the Big Bang.

In the GM the elementary rishons and antirishons have particle number $p = +\frac{1}{3}$ and $p = -\frac{1}{3}$, respectively. Thus the particle number p allotted to a composite lepton or quark reflects its degree of matter or antimatter nature. In the GM the quarks are composed of both rishons and antirishons so that they have both a matter and an antimatter nature, although an electron is composed of three \bar{T} -rishons so that it has $p = -1$ and is pure antimatter.

The solution of the matter-antimatter asymmetry problem involves the particle number additive quantum number p of the GM: in particular the values of p corresponding to a weak eigenstate up quark ($p = +\frac{1}{3}$), a weak eigenstate down quark ($p = +\frac{1}{3}$) and an electron ($p = -1$). The values of $p = +\frac{1}{3}$ of the quarks, correspond to the values of their baryon number in the SM, while the value of $p = -1$ of the electron, corresponds to minus the value of the lepton number of the electron in the SM. In the GM, the electron consists entirely of antirishons, i.e. antiparticles, while in the SM it is assumed to be a particle, although as we have indicated earlier, there is no a priori reason for this assumption. It should be noted that the matter/antimatter nature of an electron in the GM is not merely a revised definition of the term “matter” but is a requirement for consistency of the nature of the constituents of the electron and the initial particle-antiparticle nature of the universe in the Big Bang: the elementary particles in the SM (leptons and quarks) and in the GM (rishons) are different.

In the GM the proton is assumed to consist of three weak eigenstate quarks, two up quarks and one down quark, so that the proton has particle number $p = +1$. Consequently, a hydrogen atom, consisting of one proton and one electron has particle number $p = 0$: the hydrogen atom in the GM consists basically of an equal number of rishons and antirishons, so that there is no asymmetry of matter and antimatter there.

In the GM the neutron consists of three weak eigenstate quarks, one up quark and two down quarks, so that the neutron also has particle number $p = +1$. Consequently, a helium atom, consisting of two protons, two neutrons and two electrons has particle number $p = +2$: the helium atom in the GM consists of six more rishons than antirishons, i.e. more matter than antimatter. In the GM it is assumed that during the formation of helium in the aftermath of the Big Bang that an equivalent surplus of antimatter was formed as neutrinos, which have $p = -1$, so that overall equal numbers of rishons and antirishons prevailed. This assumption is a consequence of the conservation of p in all interactions in the GM.

Thus the ordinary matter present in the universe, prior to the fusion process into heavier elements, has particle number $p = 0$. Since the additive quantum number p is conserved in all interactions, this implies that the overall particle number of the universe will remain as $p = 0$, i.e. symmetric in particle and antiparticle matter.

Indeed it should be noted that if the Big Bang produced equal numbers of particles and antiparticles so that the initial state of the universe had particle number $p = 0$, then the GM *predicts* that the present state of the universe should also have $p = 0$, since particle number p is conserved in all interactions.

To summarize: the ordinary matter present in the universe has an overall particle number of $p = 0$, so that it contains equal numbers of both rishons and antirishons. This implies that the original antimatter created in the Big Bang is now contained within the stable composite leptons, i.e. electrons and neutrinos, and the stable composite quarks, i.e. the weak eigenstate up and down quarks, which comprise the protons and neutrons. The hydrogen, helium and heavier atoms all consist of electrons, protons and neutrons. This explains where all the antiparticles have gone. Thus there is no matter-antimatter asymmetry in the present universe.

However, the above does not explain why the present universe consists primarily of hydrogen atoms and not antihydrogen atoms. In the SM this is considered to be the matter-antimatter asymmetry problem, since each of the elementary particles, the electron and both the up and down quarks are defined to be matter (particles). In the GM it has been demonstrated that this is not so: both hydrogen atoms and antihydrogen atoms have $p = 0$, consisting of six rishons and six antirishons. Indeed an antihydrogen atom consists of the same rishons and antirishons as does a hydrogen atom, although the rishons and antirishons are differently arranged in the two systems. A hydrogen atom consists of a proton (six rishons and three antirishons) and an electron (three antirishons), while an antihydrogen atom consists of an antiproton (three rishons and six antirishons) and a positron (three rishons).

This implies that both hydrogen atoms and antihydrogen atoms should be formed during the aftermath of the Big Bang with about the same probability. In fact, estimates from the cosmic microwave background data suggest [11] that for every billion hydrogen-antihydrogen pairs there was just one extra hydrogen atom. It is suggested that this extremely small difference, one extra hydrogen atom in 10^9 hydrogen-antihydrogen pairs, may arise from statistical fluctuations associated with the complex many-body processes involved in the formation of either a hydrogen atom or an antihydrogen atom. The uniformity of the universe [11], in particular

the lack of antihydrogen throughout the universe, indicates that the above statistical fluctuations took place prior to the “inflationary period” [33, 34] associated with the Big Bang scenario.

7. Gravity

Let us now consider the nature of gravity within the framework of the GM. It is considered that the rishons of each colorless lepton, e.g. an electron, are very strongly localized since to date there is no direct experimental evidence for any substructure of these particles. It is expected that the product wave function describing the distribution of the constituent rishons is significant for only an extremely small volume of space so that the color fields almost cancel. It should be noted that the color fields would only cancel completely if each of the rishons occupied the same position, but quantum mechanics prevents this. This raises a question: *What is the residual interaction arising from the incomplete cancellation of the strong interactions?*

Between any two colorless leptons (e.g. electrons) there will be a very weak residual interaction, arising from the color interactions acting between the color charges of one lepton and the color charges of the other lepton. There will be a similar residual interaction between any two colorless hadrons such as neutrons and protons, each containing three differently colored quarks.

In two papers [3, 4] it was suggested that this residual interaction, arising from these “interferion” color interactions, gives rise to the usual gravitational interaction.

The mass of a body of ordinary matter is essentially the total mass of its constituent colorless electrons, neutrons and protons. Each of these three composite particles is in a three-color antisymmetric state so that its behavior with respect to the color interactions is basically the same. This suggests [13] that the residual color interactions between electrons, neutrons and protons have several properties associated with the usual gravitational interaction: universality, very weak strength and attraction.

In the GM gravity essentially arises from the residual color forces between all electrons, neutrons and protons. This leads [13] to a *new law of gravity*: the residual color interactions between any two bodies of masses m_1 and m_2 , separated by a distance r , leads to a universal law of gravitation, which closely resembles Newton’s original law given by:

$$F = H(r) m_1 m_2 / r^2, \quad (3)$$

where Newton’s gravitational constant (G) is replaced by a function of r , $H(r)$.

The new gravitational interaction of the GM is based upon the residual color interactions acting between electrons, neutrons and protons. The GM assumes that the color interactions acting between rishons have the same characteristics as the color interactions acting between quarks in the SM. These color interactions have two important properties that differ from the Newtonian interaction: (i) asymptotic freedom [9, 10] and (ii) color confinement [11]. These determine the nature of the function $H(r)$.

In Sections 8 and 9, we shall indicate how these two additional properties of the interfermion color interactions provide an understanding of dark matter and dark energy, respectively.

8. Galaxy rotation problem and dark matter

For galaxies there is a major gravitational problem [12], which has been around for about 40 years. It was found that the rotation curves for galaxies disagreed with Newton's gravitational law for large r : the stars and gas were rotating much faster than expected from Newton's law and their orbital velocities were roughly constant. These observations implied that either Newton's law was incorrect at large distances or some considerable mass was missing.

The rotation curve for a galaxy is the dependence of the orbital velocity of the visible matter in the galaxy on its radial distance from the center of the galaxy. What the observations showed was that the rotation curves were essentially "flat" at the extremities of the visible matter, i.e. at large distances. This implies gross disagreement with Newton's universal law of gravitation, which predicts a fall-off as $1/\sqrt{r}$, as in the solar system.

Two solutions, which have been very successful, are first the *dark matter hypothesis*, which proposes that a galaxy is embedded within a giant halo of dark matter. This matter is considered to be nonatomic but otherwise its nature is unknown and so far has not been detected. The second solution is the *Modified Newtonian Dynamics* (MOND) hypothesis: Milgrom [35] proposed that gravity varies from Newton's law for low accelerations. This was an empirical hypothesis without physical understanding.

It was found that the *new law of universal gravitation* given by Eq. (3) is essentially equivalent to the MOND hypothesis so that the GM gravitational interaction provides a physical basis for the MOND hypothesis. The continuing success [36, 37] of the MOND hypothesis is a strong argument against the existence of undetected dark matter haloes, consisting of unknown matter embedding galaxies.

Asymptotic freedom is rather a misnomer. A better term is "antiscreening" as used by Wilczek in his 2004 Nobel lecture. The flat galactic rotation curves are described by the property of antiscreening provided by the self-interactions of the hypergluons mediating the residual color interactions. These antiscreening effects lead to an increase in the strength of the residual color interactions so that $H(r)$ becomes an increasing function of r . The flat rotation curves observed for galaxies indicate that:

$$H(r) = G(1 + kr), \quad (4)$$

where k is a factor representing the relative strengths of the modified and Newtonian gravitational fields.

In the GM $H(r) = G(1 + kr)$ arises from the self-interactions of the hypergluons mediating the gravitational interaction and explains the dark matter problem of the galaxy rotational curves: for small r , $H(r)$ is approximately G and gravity is approximately Newtonian; for large r , $H(r)$ is approximately Gkr and gravity is approximately $1/r$ rather than $1/r^2$, and the $1/r$ dependence gives the flat rotation curves observed.

9. Dark energy

Color confinement is the phenomenon that color charged particles (e.g. quarks in the SM, rishons in the GM) cannot be isolated and consequently form colorless composite particles (e.g. mesons and baryons in the SM and also leptons in the GM). Color confinement leads to another phenomenon analogous to the “hadronization process” [11], i.e. the formation of hadrons out of quarks and gluons in the SM and implies $H(r) = 0$ for sufficiently large r in the GM [13].

In the GM, $H(r) = 0$ arises if the gravitational field energy is sufficient that it is energetically favorable to produce the mass of a particle-antiparticle colorless pair rather than the color field to extend further. This implies that gravity ceases to exist for sufficiently large cosmological distances.

The strong color interaction is known to have a finite range of approximately 10^{-15} m. Gravity is about 10^{-41} times weaker at 10^{-15} m [11] than the strong color interaction. This suggests that the “hadronization process” for gravity occurs at about 10^{26} m, i.e. roughly ten billion light years.

The new law of gravity implies that gravity ceases to exist for cosmological distances exceeding several billion light years, resulting in less slowing down of galaxies than expected from Newton’s law. This result agrees well with observations [38, 39] of distant Type Ia supernovae, which indicate the onset of an accelerating expansion of the universe at about six billion light years. Thus the new law of gravity suggests that dark energy like dark matter may be understood as an effect arising from the nature of the gravitational interaction.

10. Photon

The nature of the photon within the framework of the GM is worthy of consideration. The photon has several properties that may be accommodated in the GM: (i) massless; (ii) neutral; (iii) colorless; (iv) spin-1; (v) $U(1)$ symmetry and (vi) interacts with matter gravitationally.

It is proposed that the photon may be the *singlet state* of the corresponding QCD color octet binding together the rishons and antirishons of the leptons and quarks. If the photon is the standard singlet state of QCD: $[(r\bar{r}) + (g\bar{g}) + (b\bar{b})]/\sqrt{3}$, containing all three color charges, red (r), green (g) and blue (b) and all three anticolor charges, antired (\bar{r}), antigreen (\bar{g}) and antiblue (\bar{b}), then it has each of the above six properties possessed by the photon.

In the GM the singlet state is a hypergluon, which is massless, electrically neutral, colorless and has spin-1 and $U(1)$ symmetry. Furthermore, in the GM it interacts with matter via the new gravitational interaction based upon the residual color interactions. In particular the GM predicts that it leads to *twice* the deflection of Newton’s universal theory of gravity in agreement with Einstein’s theory of general relativity but without any warping of spacetime. In this way the electromagnetic and strong color interactions are *unified* within a $U(3) = U(1) \times SU(3)$ symmetry.

11. Summary and conclusion

The GM considers that the elementary particles of the SM, the leptons, quarks and weak bosons are all composite particles. This substructure leads to new paradigms for both mass and gravity, which in turn lead to an understanding of several cosmological problems: the matter-antimatter asymmetry of the universe, dark matter and dark energy.

The GM provides a *unified* origin of mass and the composite nature of the leptons and quarks leads to a solution of the cosmological matter-antimatter asymmetry problem.

The GM also provides a new universal quantum theory of gravity. In the GM, gravity is a very weak residual interaction of a strong color-like interaction, which possesses two important properties: antiscreening and finite range that provide an understanding of dark matter and dark energy, respectively, in terms of gravitational effects.

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